

CLAIMS

1. A micro-mirror device, comprising:
 - a substrate having a surface;
 - 5 a pair of electrodes disposed adjacent to the surface of the substrate and spaced apart from each other;
 - a reflective element spaced from the surface of the substrate; and
 - a dielectric liquid disposed at least between the reflective element and the pair of electrodes, wherein the reflective element is adapted to be positioned at any
 - 10 position within a continuous range between a first position and a second position in response to analog electrical signals applied to the pair of electrodes.
2. The device of claim 1, wherein said first and second positions of the reflective element are oriented in directions on opposite sides of a neutral position of the micro-mirror device.
- 15 3. The device of claim 1, wherein said first position of the reflective element is a neutral position of the micro-mirror device.
4. The device of claim 1, wherein said second position of the reflective element is a neutral position of the micro-mirror device.
5. The device of claim 1, wherein said first position of the reflective element is
- 20 oriented at an angle to the second position.
6. The device of claim 1, wherein said first position of the reflective element is oriented at an angle to a neutral third position between said first and second positions.
7. The device of claim 1, wherein said second position of the reflective element
- 25 is oriented at an angle to a neutral third position between said first and second positions.

8. The device of claim 1, wherein the reflective element is positioned above the dielectric liquid.

9. The device of claim 1, wherein the reflective element is submerged in the dielectric liquid.

5 10. The device of claim 1, wherein the plate is transparent.

11. The device of claim 1, wherein the dielectric liquid is transparent.

12. The device of claim 1, further comprising:

at least one post extending from the surface of the substrate and supporting the reflective element relative to the surface of the substrate.

10 13. The device of claim 12, further comprising:

at least one hinge supporting the reflective element from the at least one post, wherein the at least one hinge is adapted to facilitate movement of the reflective element between the first position and the one second position.

14. The device of claim 13, wherein the at least one hinge includes a torsional

15 member adapted to twist about a longitudinal axis thereof.

15. The device of claim 13, wherein the at least one hinge includes a flexure member adapted to bend along a longitudinal axis thereof.

16. The device of claim 12, further comprising:

20 a conductive via extending through the at least one post and being electrically coupled to the reflective element.

17. The device of claim 12, wherein the reflective element includes a substantially rectangular-shaped portion having four contiguous side portions, wherein the at least one post is positioned within the four contiguous side portions.

18. The device of claim 12, wherein the reflective element includes a substantially rectangular-shaped portion, wherein the at least one post is positioned to a side of the rectangular-shaped portion.

19. The device of claim 1, further comprising:

5 at least two conductors formed on the surface of the substrate and electrically coupled to the pair of electrodes for applying said analog electrical signals to the pair of electrodes.

20. The device of claim 1, wherein the reflective element includes a conductive material.

10 21. The device of claim 20, wherein the reflective element includes a reflective material disposed on the conductive material.

22. The device of claim 20, wherein the reflective element is adapted to move in response to application of an analog electrical signal to the conductive material.

15 23. The device of claim 1, wherein the dielectric liquid is adapted to increase an actuation force on the reflective element as generated by a given applied voltage.

24. The device of claim 1, wherein the dielectric liquid is adapted to transfer heat within the micro-mirror device.

20 25. The device of claim 1, wherein drive circuitry for the micro-mirror device is formed in the substrate.

26. The device of claim 1, wherein the reflective element includes a conductive material, and wherein the reflective element is adapted to move in response to application of an electrical signal to the pair of electrodes and the conductive material.

25 27. The device of claim 1, wherein the pair of electrodes includes a first electrode formed on the surface of the substrate adjacent to a first end of the reflective element and a second electrode formed on the surface of the

substrate adjacent to a second end of the reflective element opposite the first end thereof.

28. The device of claim 27, wherein the reflective element is adapted to move in a first direction in response to application of an electrical signal of a first polarity
5 and to move in a second direction opposite the first direction in response to application of an electrical signal of a second polarity.

29. A display device including the micro-mirror device of claim 1.

30. A display comprising an array of the display devices of claim 29.

31. A micro-mirror device, comprising in combination:

10 a substrate having a surface;

means for reflecting light, the light-reflecting means being spaced from the surface of the substrate;

plural means for moving the light-reflecting means, said plural means for moving being disposed adjacent to the surface of the substrate and spaced apart from
15 each other; and

means for insulating said light-reflecting means from the means for moving, said insulating means being disposed at least between the light-reflecting means and the means for moving, wherein the light-reflecting means is adapted to be positioned at any position within a continuous range between a first position and
20 a second position in response to analog electrical signals applied to the means for moving the light-reflecting means.

32. A method of using a micro-mirror device having a reflective element, a pair of electrodes spaced from the reflective element, and a dielectric liquid disposed at least between the reflective element and the pair of electrodes, said method
25 comprising the steps of:

electrically coupling to the pair of electrodes an operational amplifier having an output for coupling to at least one of the pair of electrodes and having inverting and non-inverting inputs;

electrically coupling the reflective element to the inverting input of the operational amplifier to provide feedback; and

applying an analog positioning signal to the non-inverting input of the operational amplifier, whereby the reflective element is positioned at a selected
5 position within a continuous range between a first position and a second position in response to the applied analog positioning signal.

33. The method of claim 32, further comprising the step of:

mixing a dithering signal with said analog positioning signal.

34. A method of fabricating a micro-mirror device, the method comprising the
10 steps of:

providing a substrate having a surface;

providing a plate oriented substantially parallel to the surface of the substrate and spacing the plate from the surface of the substrate, including defining a cavity between the plate and the surface of the substrate;

15 disposing a dielectric liquid in the cavity; and

interposing a reflective element between the surface of the substrate and the plate, wherein the reflective element is adapted to move to a selected position within a continuous range between a first position and a second position.

35. The method of claim 34, wherein the plate and the dielectric liquid are
20 transparent.

36. The method of claim 34, wherein interposing the reflective element between the surface of the substrate and the plate includes submerging the reflective element in the dielectric liquid.

37. The method of claim 34, wherein interposing the reflective element between
25 the surface of the substrate and the plate includes positioning the reflective element above the dielectric liquid.

38. The method of claim 34, wherein the second position of the reflective element is oriented at an angle to the first position.

39. The method of claim 34, further comprising:

extending at least one post from the surface of the substrate, wherein

5 interposing the reflective element between the surface of the substrate and the transparent plate includes supporting the reflective element relative to the surface of the substrate from the at least one post.

40. The method of claim 39, further comprising:

extending at least one hinge between the at least one post and the reflective

10 element, wherein the at least one hinge is adapted to facilitate movement of the reflective element between the first position and the at least one second position.

41. The method of claim 40, wherein the at least one hinge includes a torsional member adapted to twist about a longitudinal axis thereof.

15 42. The method of claim 40, wherein the at least one hinge includes a flexure member adapted to bend along a longitudinal axis thereof.

43. The method of claim 39, further comprising:

extending a conductive via through the at least one post and electrically coupling the conductive via with the reflective element.

20 44. A micro-mirror device fabricated by the method of claim 34.